Impacts by Compact Ultra Dense Objects

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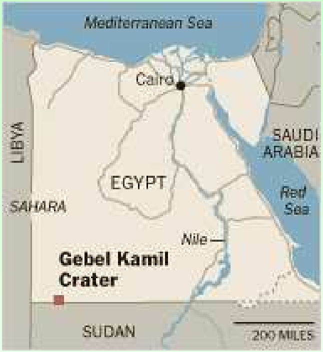
Three Days of Strong Correlations in Dense Matter,
Wrocław, October 9-12, 2019

Something hits the Earth

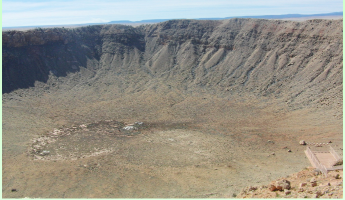
There can be lots of visible impactor material



Iron-nickel (20%) Gebel-Kamil: East Uweinat Desert, Egypt: 44.8m in diameter, 15.8m deep meteorite crater: 1600 kg of iron meteorite shrapnel, 3400 kg >10 g pieces remained today. The 1.3 meters wide 5 to 10 tons meteorite was disrupted into thousands of fragments located up to 200 m from the crater rim, largest known fragment 83 kg. Dated to about 4,500 years, explored first 2009/10. A possible source of Egypt-Pharaoh Iron.

Or there is nothing

Where is the Meteorite that made our Arizona Meteor ‘Barringer’ Crater?



This is about 1.5 km wide and 200 m. deep recent (50 000 y old) crater where many tourists in Arizona visit. 110 years ago Daniel Barringer searched to profit from what he expected to be 2.510^6 tons of iron-nickel content of the meteorite. It was found: a few (3!) meteorite fragments found in riverbeds many miles away. Short of a space ship crash site, of which remains were carefully removed, what is the causes for this gigantic hole in the ground? There are many other “missing meteorite” impacts

Missing meteorite case is not singular

Some examples

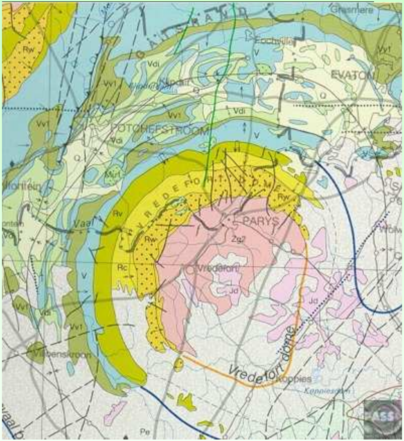
Pingaluit Crater: Diameter 3.44 km, Depth 400 m, dated $1.4 \pm 0.1 \times 10^6$y old

Lonar crater: Diameter 1.8 km, dated 0.6×10^6y old. Hole in basalt flow from 50 million years ago

Despite prolonged searches practically no cosmic material was discovered

Missing meteorite case is not singular

John W. MORGAN et. al. ^{190}Pt-^{186}Os and ^{187}Re-^{187}Os systematics of the Sudbury Igneous Complex, Ontario; Geochim. et Cosmochim. Acta **66**,(2),273-290 (2002)



4.2. Where is the Meteorite?

It is generally agreed now that the SIC was generated by a meteorite impact, and yet little evidence has been found of the signature of the impacting body. Highly siderophile elements (primarily PGE and particularly Ir) are a sensitive indicator of meteoritic influx (Peucker-Ehrenbrink and Ravizza, 2000) and impact (Evans et al., 1993). Siderophile element analysis has been outstandingly successful in identification of the world-wide chondritic signature of impact at the Cretaceous–Tertiary boundary (Ganapathy, 1980; Kastner et al., 1984; Evans et al., 1993), but this achievement has distracted attention from puzzling results at impact craters recognized by other criteria. Melt rocks from smaller craters often carry a signature of the impactor as, for example, at the 8.5 km Wanapitei Lake crater (Wolf et al., 1980; Grieve and Ber, 1994). In craters larger than ca. 30 km diam., however, melt rocks often show little or no PGE enrichment as at the 70 km Manicouagan, Quebec crater (Wolf et al., 1980). Nevertheless, the size distinction is not always clearcut since small craters such as the 1.8 km diameter Lonar, India, crater may be found with no meteoritic signature (Morgan, 1978), whereas the ≈70 km Morokweng, South Africa, crater has impact melts containing large amounts of siderophiles (Koeberl et al., 1997; Reimold and Koeberl, 1999).

Sudbury, Canada: major mining districts of the world, where “something” called an impact seems to have pulled from the depth the Earth siderophile metals.

BBC: 10 October 1465 Event

The massive volcano that scientists can't

BBC
By Zaria Gorvett
3 July 2017

It was the biggest eruption for 700 years but scientists still can't find the volcano responsible.

It was 10 October 1465 – the day of the hotly anticipated wedding of King Alfonso II of Naples. He was set to marry the sophisticated Ippolita Maria Sforza, a noblewoman from Milan, in a lavish ceremony.

Though it was the middle of the day, the Sun had **turned a deep azure**, plunging the city into eerie darkness.

This was just the beginning. In the months that followed, European weather went haywire. In Germany, it rained so heavily that corpses surfaced in cemeteries. In the town of Thorn, Poland, the inhabitants took to travelling the streets by boat. In the unrelenting rain, the castle cellars of Teutonic knights were flooded and whole villages were swept away.

Four years later, Europe was hit by a mini ice age.

The thing is, scientists can't find the volcano that did it. What's going on?

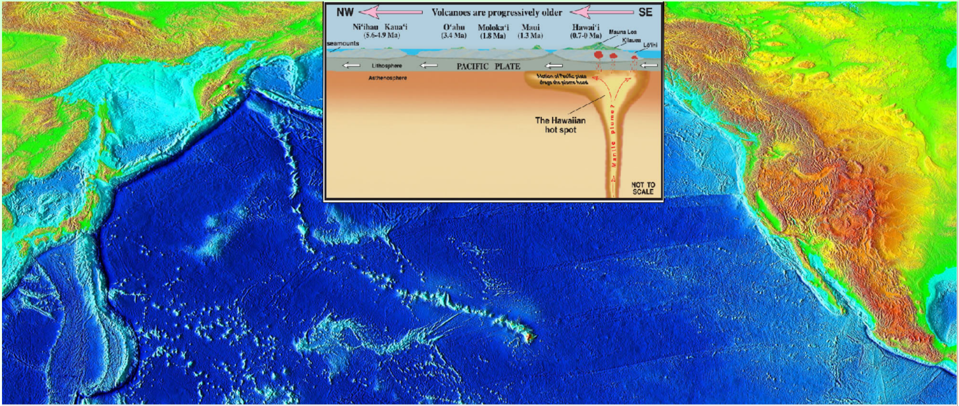
... produced an ash cloud which enveloped the Earth and led to the coolest decade for centuries.

“ *This is a true geological mystery, which has left geologists scratching their heads for decades*

That the 'unknown eruption' happened is undisputed – like most mega-eruptions, it vapourised vast quantities of sulphur-rich rock, which was blasted into the atmosphere and eventually snowed down on the poles as sulphuric acid. There it was locked into the ice, forming part of a natural record of geological activity that spans millennia. There's no other event capable of doing this, short of an asteroid impact.

Some Earth puncture leaves a lasting damage that cures slowly

Hawaii is a 'hot-spot': the central pacific plate moving NW over the deep hot spot giving birth to chain of a dozen islands



Comet Lovejoy survives encounter with Sun

SOHO C2 IMAGE AND MODEL OF DUST TAIL OF C/2011 W3 ON DEC. 16

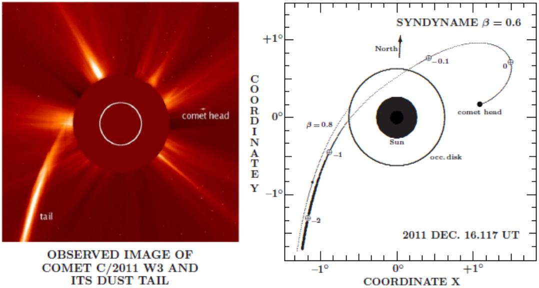


Figure 8. Appearance of comet C/2011 W3 and its dust tail in an image taken with the C2 coronagraph on board the *SOHO* spacecraft on December 16.117 UT, or 0.105 days after perihelion. The tail, to the south-southeast of the Sun, is seen to be completely disconnected from the comet's head, to the west of the Sun.

THE ASTROPHYSICAL JOURNAL, 757:127 (33pp), 2012 October 1 doi:10.1088/0004-637X/757/2/127

COMET C/2011 W3 (LOVEJOY): ORBIT DETERMINATION, OUTBURSTS, DISINTEGRATION OF NUCLEUS, DUST-TAIL MORPHOLOGY, AND RELATIONSHIP TO NEW CLUSTER OF BRIGHT SUNGRAZERS

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ABSTRACT

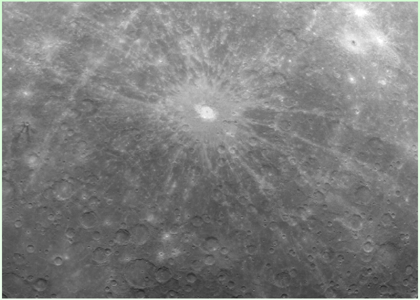
We describe the physical and orbital properties of C/2011 W3. After surviving perihelion passage, the comet was observed to undergo major physical changes. The permanent loss of the nuclear condensation and the formation of a narrow spine tail were observed first at Malargue, Argentina, on December 20 and then systematically at Siding

More Mars, Mercury star-rayed craters?

Mars:

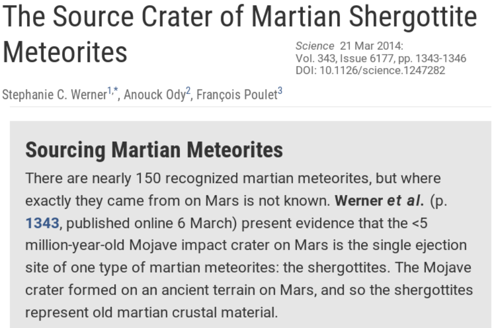
A dramatic Mars impact crater created between July 2010 and May 2012 photographed by HiRISE camera on board NASA's Mars Reconnaissance Orbiter on Nov. 19, 2013. The 30 meters in diameter crater is surrounded by a 15km large, rayed blast zone.

Mercury:



Mojave Crater on Mars: Source of 80% Mars impactors on Earth – 55km large ‘recent crater’

. . . 55-kilometer-wide Mojave crater on Mars formed 3-5 million years ago. Based on their cosmic ray exposure, the shergottites from Mars must have broken off between 1 and 5 million years ago.

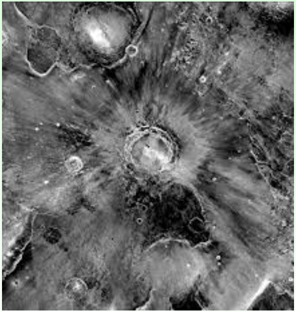

The Source Crater of Martian Shergottite Meteorites

Science 21 Mar 2014:
Vol. 343, Issue 6177, pp. 1343-1346
DOI: 10.1126/science.1247282

Stephanie C. Werner[1,*], Anouck Ody[2], François Poulet[3]

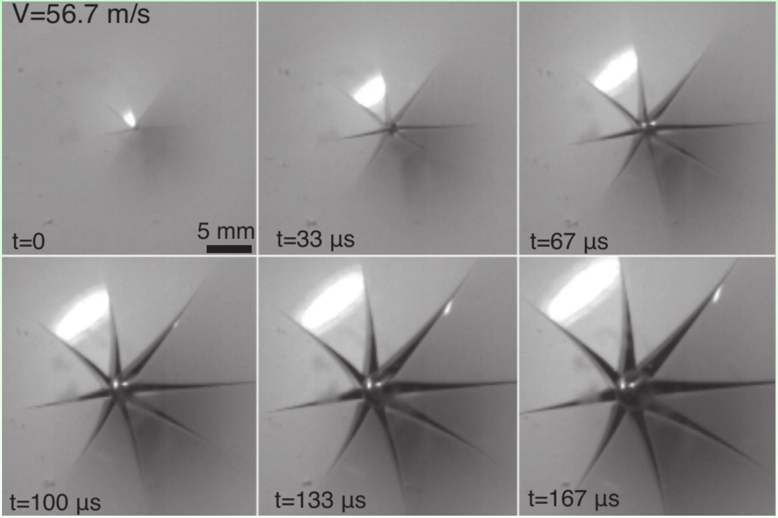
Sourcing Martian Meteorites

There are nearly 150 recognized martian meteorites, but where exactly they came from on Mars is not known. **Werner *et al.*** (p. 1343, published online 6 March) present evidence that the <5 million-year-old Mojave impact crater on Mars is the single ejection site of one type of martian meteorites: the shergottites. The Mojave crater formed on an ancient terrain on Mars, and so the shergottites represent old martian crustal material.



Note rayed structure

A simple model: Shot across glass plate



Glass shot from: Nicolas Vandenberghe, Romain Vermorel, Emmanuel Villermaux. *Physical Review Letters* **110** 174302 (2013)

Impossible becomes a reality

It looks as

In all cases the impactor has vanished by entering deep into the Earth.

But

For normal matter impactors

No existent impact model allows such penetration of the surface

So

This means

Some very strange thing must be flying around - **a new form of non-normal matter**

CUDO=Compact UltraDense Object

DO NOT confuse with Compact Unidentified Object!

Space bodies and meteors made of very dense matter

Examples

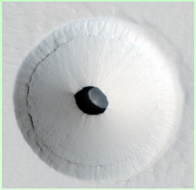
- STRANGElet fragments of neutron stars,
- dark matter bound objects,
- micro-black-holes

These are a few discussed in literature.

Related definitions

- kudos (from Greek kyddos, singular)= honor; glory; acclaim; praise
- čudo (Slovak)= miracle
- cud (Polish pronounced c-ood) = miracle
- cudo (colloq. Polish, pronounced c-oodoh) = of surprising and exceptional character (sometimes gender related)

CUDO - more examples



Mars-hole Hirise#2560

HAPPY BIRTHDAY, DAVID!

No miracles, only physics!

CUDO in the Institute of Theoretical Physics
University Wrocław

CUDO allows to explain

- **“Disappearing” giant (iron-nickel) meteorites**
- **Volcanic hot-spots in middle of thick continental crust**
- **Mantle plumes: deep origin of magma and long-term stability, (some not vertical!)**
- **Dual impact/volcanic activity ‘nuclear winter” climate events**
- **Young (post-cooling) volcanic activity on Moon, Mars**
  (not described in detail today)
- **Recent large rayed crater on Mars, transfer of material to Earth**
- **Comets fly through Sun**
- **Superdense extraterrestrial bodies**

Earth (all rocky bodies) seem to be punctured many times
(crust puncture not possible with normal matter impactor [Ivanov, Geology, 31 (2004)])

Collisions: Stopping, Other Characteristics

Entrainment of Material

Captured matter acquires CUDO velocity $\Rightarrow$ reduces CUDO speed, damage in target also reduces speed Expect $\Rightarrow$ Two surface punctures! Entry and Exit signatures

Drag from Normal matter interactions

- Mixing of nearby entrained and nearly-entrained material

Pulling debris stream along behind CUDO

- Matter from previous collisions can “dress” CUDO,
  giving appearance of normal (but overdense) meteor
- Fraction remains bound to impacted planet,
  but re-distributed inside and above surface

Two CUDO structure candidates

Impactors

We will from now on be considering a new family of cosmic impactors composed predominantly from some yet unknown form of matter.

1. Stable fragments of neutron stars = nuclear ‘strangelets ’
2. Dark matter starlets
   (self-interacting DM; maybe gravity bound DM)

NOTE: Most stuff of interest maybe hanging out in the Universe and we run into it plowing along with the Solar system and our galaxie, this means collisions involve speeds of a few hundred km/s rather than usual meteor few 10km/s.

CUDO matter example

Strangelets: *uds*-symmetric matter

$p = uud, n = ddu, \Lambda = uds$
Piece of $n_u \simeq n_d \simeq n_s$ matter, large baryon number A

Argument for (meta)stability

Chemical equilibrium:

$$\mu_d = \mu_u = \mu_s$$

Charge neutrality:

$$\frac{2}{3}n_u - \frac{1}{3}n_d - \frac{1}{3}n_s = 0$$

Thermodynamic potentials $\Omega_{u,d} = -\frac{\mu_{u,d}^4}{4\pi^2}$

With massive strange quark

$$\Omega_s = -\frac{\mu_s^4}{4\pi^2}\left(\sqrt{1-x^2}(1-\frac{5}{2}x^2) + \frac{3}{2}x^4\ln(x^{-1} + \sqrt{x^{-2}-1})\right);\ x = m_s/\mu_s$$

Third fermi sea reduces energy/baryon

$$E/A(3\text{ flavors}) < E/A(2\text{ flavors})$$

Proposed sources of Strangelets

1. Cosmological

First order phase transition to hadronic vacuum [Witten,PRD,30(1984)]

Objects $A < 10^{55}$ evaporate at $T \simeq 50\ \mathrm{MeV}$ [Alcock & Farhi,PRD,32(1985)]

Strangeness enriched at surface $\rightarrow$ reduced emissivity of nucleons

$$** \text{ Quasi-equilibrium } A \sim 10^{46} \Leftrightarrow M \simeq 10^{19}\ \mathrm{kg} = 10^{-5} M_{\mathrm{Earth}} \ **$$

[Madsen,PRD,34(1986) & 43(1991)]

- Large objects $A \gtrsim 10^{23} \Omega^3_{\mathrm{nug}} h^6 f^3_N$ consistent with BBN
- Quark matter in nuggets does <u>not</u> contribute to BBN limit on Ω_b

2. Strangeness in depth of compact stars and in HIC

Gravitational pressure can help stabilize SQM.
Neutron star mergers or collisions eject fragments.
[Madsen,JPG,28(2002) & Bauswein,PRL,103(2009)]
C. Greiner, P. Koch and H. Stoecker,*"Separation of Strangeness from Antistrangeness in the Phase Transition from Quark to Hadron Matter...,"* Phys. Rev. Lett. **58**, 1825 (1987).

Strangelet Mass and Size Scales

Strangelet = piece of $n_u \simeq n_d \simeq n_s$ matter, large baryon number A

Madsen astro-ph/9809032, astro-ph/0612740

$$10^{30} < A < 10^{56} \quad \Leftrightarrow \quad \begin{cases} 10^4\ \mathrm{kg} < M < 10^{29}\ \mathrm{kg} \\ 10^{-20} < M/M_{\mathrm{Earth}} < 10^5 \end{cases}$$

- Constant density: $M \sim R^3$
- Density scale set by nuclear length $R_{\mathrm{nuc}} \sim 1\ \mathrm{fm}$ (10^5 reduction relative to normal matter atomic length $R_{\mathrm{atom}} \sim 1$Å)

Normal matter asteroid	SQM "asteroid"
$M \sim 10^{-5} M_{\mathrm{Earth}}$	$M \sim 10^{-5} M_{\mathrm{Earth}}$
$R \sim 100\ \mathrm{km}$	$R \sim 1\ \mathrm{m}$

Compactness and high density $\rho_{\mathrm{nuc}} \sim 10^{15} \rho_{\mathrm{atomic}}$ mean

- ▶ gravity relevant in interactions: $g_{\mathrm{surf}} = \dfrac{GM}{R^2} = \dfrac{4\pi G}{3}\rho R$
- ▶ Matter cannot support a strangelet: "punctures the Earth"

[see e.g. DeRujula/Glashow, Nature,312(1984), Herrin et al,PRD,53(1996) & 73(2006)]

More about this

- *Compact ultra dense matter impactors*
  J. Rafelski, L. Labun and J. Birrell, Phys. Rev. Lett. **110**, no. 11, 111102 (2013) http://prl.aps.org/abstract/PRL/v110/i11/e111102
- *Properties of Gravitationally Bound Dark Compact Ultra Dense Objects*
  C. Dietl, L. Labun and J. Rafelski, Phys. Lett. B **709**, 123 (2012) http://www.sciencedirect.com/science/article/pii/S0370269312001463
- *Compact Ultradense Objects in the Solar System*
  J. Rafelski, C. Dietl and L. Labun, Acta Phys. Polon. B **43**, no. 12, 2251 (2012) http://th-www.if.uj.edu.pl/acta/vol43/abs/v43p2251.htm
- *Planetary Impacts by Clustered Quark Matter Strangelets*
  L. Labun and J. Rafelski, Acta Phys. Polon. Supp. **5**, 381 (2012) http://dx.doi.org/10.5506/APhysPolBSupp.5.381

Dark Matter is Matter

From standard cosmology, fractions of **N**on-**B**aryonic and **B**aryonic gravitating matter show $4/5$ of gravitating matter not identified: 'dark'

Bullet Cluster, Abell 520, etc show
– Separation of luminous matter and gravity source
$\Rightarrow$ evidence of independent dynamics
$\Rightarrow$ small self-interaction

Many candidate particles could mean *many components* of unseen 'dark' matter,

THE ASTROPHYSICAL JOURNAL, 648:L109–L113, 2006 September 10

A DIRECT EMPIRICAL PROOF OF THE EXISTENCE OF DARK MATTER[1]

DOUGLAS CLOWE,[2] MARUŠA BRADAČ,[3] ANTHONY H. GONZALEZ,[4] MAXIM MARKEVITCH,[5,6]
SCOTT W. RANDALL,[5] CHRISTINE JONES,[5] AND DENNIS ZARITSKY[2]
Received 2006 June 6; accepted 2006 August 3; published 2006 August 30

We present new weak lensing observations of 1E 0657−558 ($z = 0.296$), a unique cluster merger, that enable a direct detection of dark matter, independent of assumptions regarding the nature of the gravitational force law. Due to the collision of two clusters, the dissipationless stellar component and the fluid-like X-ray–emitting plasma are spatially

Dark Matter is (weakly) Self-Interacting

https://physics.aps.org/synopsis-for/10.1103/PhysRevLett.119.111102

Synopsis: Self-Interacting Dark Matter Scores Again

Dark matter that interacts with itself provides a better description of the speeds of stars in galaxies than dark matter that doesn't self-interact.

ESA/Hubble & NASA

Physics

September 13, 2017

Self-Interacting Dark Matter Can Explain Diverse Galactic Rotation Curves

Ayuki Kamada, Manoj Kaplinghat, Andrew B. Pace, and Hai-Bo Yu

Phys. Rev. Lett. 119, 111102 (2017)

Published September 13, 2017

Self-interacting dark matter—a hypothetical form of dark matter made of particles that interact with one another—is a problem fixer in cosmology. On galactic and smaller scales, it can fix discrepancies between observations and predictions of the standard cosmological model, which instead considers "cold" dark matter that doesn't interact with itself. And it does so while leaving intact the standard model's success on larger scales. Manoj Kaplinghat from the University of California at Irvine, Hai-Bo Yu from the University of California at Riverside, and colleagues now show that self-interacting dark matter can also explain the diversity of galaxy rotation curves—graphs of the speeds of stars in a galaxy versus their distance from the galaxy's center.

Primordial DM Meteor Possible? Qualitative Consideration

High mass/energy scale help with early-universe formation:

- Becoming non-relativistic at an earlier time, dark matter has a density proportionally higher at the time when gravity can begin to work on local density fluctuations
- CUDO comprises $10^{11} - 10^{19}$ fewer particles $\Rightarrow$ requires smaller correlation volume contributing
- Dark particle-particle gravitational interaction $10^{6} - 10^{10}$ times larger maybe capable to ‘kick out’ visible matter to bind .
- High surface acceleration CUDOs stable against gravitational disruption (especially in collisions with normal matter objects) $\Rightarrow$ persist into present era at rest in CBM frame of reference

Stellar DM Meteor formation Possible? Qualitative Consideration

- Dark matter accretion to stellar objects have been studied, concentration in stellar object cores
- Formation of gravitationally bound dark matter CUDOs unavoidable
- Stellar SN explosions practically always asymmetric, stellar core CUDO left behind

Compact stars as dark matter probes

Gianfranco Bertone and Malcolm Fairbairn
Phys. Rev. D **77**, 043515 – Published 15 February 2008

PHYSICAL REVIEW D

We discuss the consequences of the accretion of dark matter (DM) particles on compact stars such as white dwarfs and neutron stars. We show that in large regions of the DM parameter space, these objects

Difference to primordial dark CUDOs which at rest in CBM frame:
Stellar catalysis CUDOs follow galactic dynamics, have strangelet-like velocity distribution

Primordial Black Hole (PBH) as the Ninth Planet?

Observation 1

There is set of gravitational anomalies recently observed by the Optical Gravitational Lensing Experiment (OGLE).

This can correspond to lensing by objects of mass $M \sim 0.5M_{\oplus} - 20M_{\oplus}$

Observation 2

There is a growing body of observational anomalies connected to the orbits of trans-Neptunian Objects

This has been taken as evidence of a new planet (P9) of mass $M \sim 5M_{\oplus} - 15M_{\oplus}$

This can be also triggered by the PBH of $r_{BH} \sim 5\text{cm}$ and $M_{BH} \sim 5M_{\oplus}$

J. Scholtz and J. Unwin, *"What if Planet 9 is a Primordial Black Hole?,"*, arXiv:1909.11090 [hep-ph].

Some conclusions
and question marks

- There are phenomena which qualify as CUDO puncture candidates.
- Sudden and relatively frequent climate excursions in Earth history could be due to puncture impact.
- To maintain earth habitable over more then few hundred million years there is need for CUDO punctures
- Long lasting lava flow can release the deeply captured carbon back into the atmosphere, allowing organic life to resurge - global tectonics and CO_2 balance problem.